Design of the Smart Access Vehicle System with Large Scale MA Simulation

Hideyuki Nakashima
Future University Hakodate

Hitoshi Matsubara
Future University Hakodate

Keiji Hirata
Future University Hakodate

Yo Shiraishi
Future University Hakodate

Shoji Sano
Future University Hakodate

Ryo Kanamori
Nagoya Institute of Technology

Itsuki Noda
Naitonal Institute of Advanced Industrial Science and Technology

Tomohisa Yamashita
Naitonal Institute of Advanced Industrial Science and Technology

Hitoshi Koshiba
Naitonal Institute of Advanced Industrial Science and Technology

1. MOTIVATION

There are tendencies for people move into large cities worldwide. It is partly because living in small cities or villages costs more and is less convenient compared to living in large cities. As the result, small local cities become more and more costly and less and less convenient for living.

We believe that information and communication technologies (ICT) can change the situation. Internet made it easier to access world-wide information regardless of the location where people live. We believe that the next target is transportation.

Using the internet and GPS, there is a possibility of controlling all traffic in a city by a single computer system and make near optimal traffic flow. Some of the authors reported possibility of cooperative car navigation[5] and full demand bus system[3].

We are now applying this concept to Hakodate city under the name of "Smart City Hakodate" project. We are designing Smart Access Vehicle (SAV) system to replace current public transportation systems – buses and taxies.

In the following sections, we first describe our target SAV system. To implement the system in Hakodate, we have to clear some design issues. We have to first prove that the system is more effective than the current one. We will then describe our use of MA simulations in two ways.

2. RELATED WORK

There are many attempts for new transportation systems worldwide. One of the most popular form is so called a full demand bus system or a demand responsive transportation (DRT) system[1]. A small number (one to ten) of such vehicles are operated in many places, particularly in rural "low demand" areas. DRT is a service between buses and taxies. It is more efficient and convenient than buses and less expensive than taxies. To provide transportation for citizens is one of the responsibilities of the government and they provide DRT even if the system cannot pay by itself.

Proc. MASS2013

SAV system is different from other DRT systems. Our goal is to replace, or unite and enhance, current public transportation systems such as buses and taxies. Although our initial target is a mid-sized cities with population of several hundred thousand, we believe that SAV system is applicable any large cities like Tokyo or New York and make those transportations more effective. Unlike DRT systems in low demand areas, SAV system is expected to be operated with passenger fare only, without support of tax money.

Train systems are not directly eligible because their route is fixed. However, by dispatching SAV's to relay passengers from train stations with proper timing, the overall efficiency of even train system are improved.

3. SMART ACCESS VEHICLE SYSTEM

SAV system is designed to replace current public transportation systems with buses and taxies.

From users' point of view, calling a SAV is very similar to calling current demand buses:

1. A user contacts the system with the demand (the current location and the destination).
2. The system searches for a best vehicle considering their current position and future route.
3. The system tells the user the pickup point, the estimated time of pickup, and the estimated time to the destination (with a small margin of delay).

The differences are:

- Many (in Hakodate case, about 1000) vehicles are involved.
- SAV's operate in real time (reservation is optional). Since there are many vehicles, the system can pick up the passenger within a small amount of time, say 15min.
- The passenger is informed the expected time of arrival to the destination.

The system knows the locations and routes (destinations of passengers on board) of all vehicles. When a new demand arrives, the system searches for a vehicle that can pick up and deliver the passenger with minimum detour. Even when

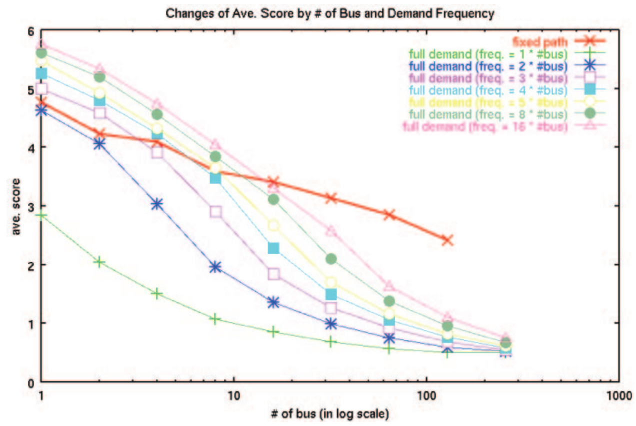

Figure 1: MA simulation on efficiency of transportation systems over population

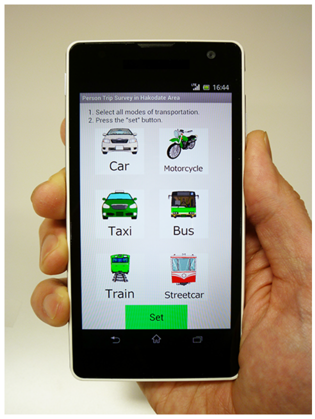

Figure 2: Smart phone application for person trip survey

a vehicle is very close to the request point, it may not be selected if a large detour, beyond the limit of promised tie of delivery, is required. If the system cannot find any vehicle, it must decline the request. We are hoping[1] that denial of service is very rare case such as a large accident or wide area disaster (including heavy storm or snow).

The central dispatch system runs on MA simulation of the city traffic. If we aim for the best solution, the computation may be too heavy. We plan to use near-optimum solution.

Besides the above basic method, we can add many options. For example, if you are really in a hurry, you can request a faster service with higher cost. Or, if you are not in a hurry, you may request slower but cheaper service. For a mass routing transit such as going to to school or office, regular bus service with fixed time-table may be more convenient because you do not have to call a SAV every day. Fixed-route and fixed-time operation is within the concept of SAV and several vehicles are reserved for the operation.

4. PERSON TRIP ANALYSIS

Fig. 1 is the result from our previous work[3] to show the superiority of the full demand bus system over conventional fix-route fix-timetable bus systems. Horizontal axis is number of vehicles (increases proportional to population). The vertical axis is average trip time to the destination. As the population, therefore number of vehicles, increase, the average trip time decreases. Conventional bus system, plotted with "x" marks, becomes more efficient as the population glows – buses in large cities are more convenient than buses in rural districts.

Full demand bus system is less efficient when the population is small, but quickly become more efficient than fixed route buses as the population grow larger. Fig. 1 just shows qualitative tendency. We do not know the quantitative population nor the number of vehicles of the cross point. To figure out those quantitative numbers of Hakodate, we plan to do the survey and MA simulation based on the survey.

To get quantitative data for simulation, we are currently surveying daily activity patterns of Hakodate citizens. We asked candidates (with variety of ages, sex and occupations) to carry mobile phones with GPS to record their positions every one minutes. We also asked them to input their goal destination, trip purpose and mode (e.g., on foot, by car, by taxi, by bus or by train). Fig. 2 is a snapshot of our application for the survey. Each candidate is supposed to continue to gather data for a couple of months. So, we made the application as simple as possible to be used daily. With gathered data, we will execute full scale simulation of Hakodate city. Although the number of the person for our person trip survey is small, we will develop a travel behavior model from the survey data, and can expand to the full scale population, 280K people, of Hakodate. We will use the actual map and bus route of Hakodate for the simulation.

In order to develop a citizen's travel behavior model, we introduce the nested logit model, which is one of a discrete choice model based on microeconomic utility maximization. In this model, each citizen is assumed to be a rational individual, and make a decision with attributes of the person and to attributes of the alternatives. For example, the utility of using the bus to shopping could be $U_{bus} = V_{bus} + error = -\beta_1 T_{bus} - \beta_2 C_{bus} + \beta_3 G + error$, where T_{bus} is the time on the bus, C_{bus} is the fare of taking the bus, G is the gender (e.g. 1 for male and 0 for female), $error$ is the error term whose distribution is Gumbel, and β_1, β_2, and β_3 are parameters that need to be estimated from real activity pattern data by a maximum likelihood method or MCMC (Markov Chain Monte Carlo) method. Similarly, the utility of using the car to shopping could be $U_{car} = V_{car} + error = -\beta_1 T_{car} - \beta_2 C_{car} + error$, where T_{car} is the driving time, C_{car} is the cost for fuel and parking. Finally, the decision would be made according to probability, $P_{bus} = exp(V_{bus})/(exp(V_{bus}) + exp(V_{car})$. In this study, we assume that the traveler's behavior in each time period is expressed as the nested logit structure that considers activity choice, destination choice, mode choice and route choice behavior.

After developing the travel behavior model base on the actual data, we can simulate each citizen's travel behavior and calculate a traffic volume which is an aggregated of each citizen's trip. In addition, if an explaining variable in a travel behavior model like the time or cost is changed, we can

[1]We plan to justify our hope with MA simulation with real Hakodate map and person trip data.

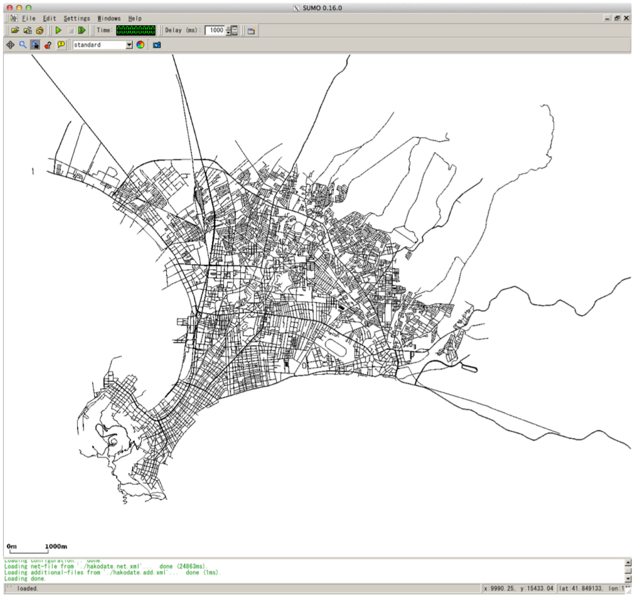

Figure 3: Road Map of Hakodate (from Open Street Map)

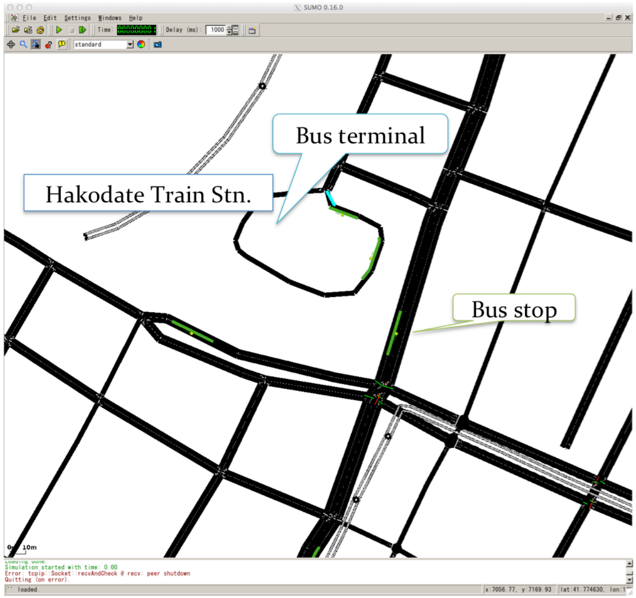

Figure 4: Zoom-in View of Road around Hakodate Train Station (from Open Street Map)

evaluate some transportation policies. We will then compare the result with another simulation of our SAV system implemented.

5. OPTIMUM ROUTING WITH MA SIMULATION

In designing optimum routing for SAV system, we utilize MA simulation to attack two issues.

The first issue is to determine vehicle assignment and routing for dynamic demands in real-time. In Hakodate, we have about 900 public transportation vehicles (200 buses and 700 taxis). Generally, it is hard to find the optimum routing for a large number of demands, because assignment problem is a kind of traveling salesman problems. Instead, we try to find semi-optimum assignment by the *successive best insertion* method[2]. In this method, the SAV center puts each demand to an auction table, where each vehicle bets with a cost value if the vehicle accepts the demand. The vehicle calculates the cost by traffic simulation based on the current holding demands and traffic situations. This semi-optimization mechanism is simple and thus flexible enough to introduce several realistic restrictions and novel services in addition to real-time problem solving.

The second issue is switching service modes. One of important results of the previous work shown in Fig. 1 is that the full demand-driven method is not an almighty system. In a certain situation, a traditional fixed-route bus system may have advantage to demand-driven system. In such case, we should choose the traditional mode[2]. In order to determine the evaluation criteria, we will apply exhaustive transportation MA simulation in which demand-driven and fixed-route

[2]In SAV system, all vehicles are center-controlled. Fixed-route operation is easily simulated by the system. Therefore, we can say that the system has full-demand mode and fixed-route mode.

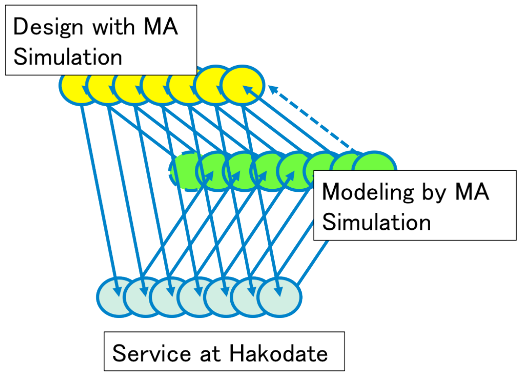

Figure 5: Design Loop

systems will be compared under various situations.

Currently, we are establishing a transportation MA simulation system for Hakodate city as shown in Figs. 3 and 4.

6. IMPLEMENTATION STRATEGY

We believe that our SAV project is a good example of service science, management, engineering and design[4]. We design a new transportation service and plan to actually implement it in Hakodate city. We exercise the design loop (Fig. 5), in which design is continuously refined through service application and (re-)modeling the result.

If the effect of the service is limited to a small region such as one office or one shop, the initial design may be directly applied. But when the effect is as large as city-wide, we cannot risk failure. Therefore, the power of multiagent simulation is maximally utilized. In our case, we use MA simulation in modeling the current status and designing a new system (routing algorithm).

It should be noted that there was an operation test of full-demand bus conducted in both in a large city and in a small city. Only one bus was deployed for both cases. The test in large city was a failure – too much detour for large amount of demand made the system inefficient. Since then, full-demand bus system was applied only in low-demand areas[1]. However, we proved with MA simulation that with full-scale deployment in large cities are efficient[3].

Overall, our first step is to use MA simulation to prove SAV system is actually more efficient than the current bus system with real data of Hakodate. Then we use MA simulation to plan the best small-scale operation test, that is to select an area and routing. With the data collected by the operation test, we will run the next cycle of design. With every cycle, we enlarge the application area.

When the full-scale SAV system is implemented to replace the current bus and taxi systems, the public transportation in Hakodate is expected to be so efficient that people may abandon driving their own cars in the city.

We further plan to fuse many urban services, such as restaurant, entertainment, sightseeing, health care, shopping and so on, on top of the core transportation system. For example, when you reserve a restaurant, SAV is reserved automatically to bring you and bring back to and from the restaurant.

The Internet changed our life with regard to getting information. Transportation is the next target of service innovation.

7. SUMMARY

We described the design of Smart Access Vehicle (SAV) system and our plan to implement it in Hakodate. Our first step is use MA simulation to prove SAV system is actually more efficient than the current bus system with real data of Hakodate. For the purpose, We are currently conducting person trip survey of Hakodate. After analyzing the result, we will run a MA simulation to show that SAV system actually works in Hakodate. Then we will put it into practical test. The whole process is a design-service-observation loop and it will be a good practice of service science.

8. REFERENCES

[1] J. Ambrosino and M. R. Nelson, editors. *Demand Responsive Transport Services: Towards the Flexible Mobility Agency.* Italian National Agency for New Technologies, Energy and the Environment, 2003. ISBN 88-8286-043-4.

[2] I. Noda, M. Ohta, Y. Kumada, K. Shinoda, and H. Nakashima. Usability of dial-a-ride systems. In *Proc. AAMAS 2005*, pages 1281–1282, 2005.

[3] I. Noda, M. Ohta, K. Shinoda, Y. Kumada, and H. Nakashima. Evaluation of usability of dial-a-ride systems by social simulation. In *Multi-Agent-Based Simulation III. 4th International Workshop, MABS 2003 (LNAI-2927)*, pages 167–81, 2003.

[4] J. Spohrer and S. K. Kwan. Service science, management, engineering, and design (ssmed): An emerging discipline – outline & references. *Int. J. of Information Systems in the Service Sector*, 1(3), 2009.

[5] T. Yamashita, K. Izumi, K. Kurumatani, and H. Nakashima. Smooth traffic flow with a cooperative car navigation system. In *Proc. AAMAS 2005*, pages 478–485, 2005.